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## A SECOND CONTRIBUTION TO THE NATURAL HISTORY OF MARL<sup>1</sup>

THE writer recently published a paper on the relation of algae to marl deposits.<sup>2</sup> Since it appeared, continued investigation has led to the discovery of additional confirmatory evidence that the close relationship there pointed out of the algae, especially *Chara*, to marl or lake lime deposits, exists to even a greater extent than was suspected.

Experimental work has been conducted along three lines, all of which have been fairly productive of results, and a brief account of this work may be of interest.

First, a series of mechanical analyses of typical white marl from different localities were made. The method of analysis used was a simple one, a modification of the beaker method used in soil analysis. The sample, chosen at random from a large specimen from the deposit under investigation, was dried in an air bath at 110° C. for sufficient time to remove any included moisture, and weighed. It was then mixed with distilled water in a large beaker and thoroughly stirred with a rubber-tipped glass rod, care being taken to stir it until all lumps caused by the adhesion of the finer particles to the coarser were broken up. Care was also taken that no more crushing should take place than was absolutely necessary. After all lumps were disintegrated, the water, with the finer particles suspended in it, was poured off into another beaker and fresh water was added to the first and the material was again stirred. This was continued until water poured into the first beaker was nearly free from finer matter and became clear on standing a few moments. The coarse material left in the bottom of the beaker was dried, sorted into various grades by a series of sieves and each grade weighed.

<sup>1</sup> Printed by permission of ALFRED C. LANE, State Geologist of Michigan.

<sup>2</sup> *JOUR. GEOL.*, Vol. VIII, No. 6. September–October 1900.

The finer material was also sorted by stirring, settling, and decantation, and the matter of different degrees of fineness dried and weighed. The finest matter was usually separated from the water by filtering through a dried and weighed filter, and the water concentrated by evaporation and again filtered to remove any of the calcium carbonate dissolved in the various processes, and the final residue of water was evaporated in a watch glass and weighed. An exceedingly interesting feature of this latter experiment was the finding of a water soluble calcium salt, in small proportion, it is true, but still easily weighable and not to be neglected. The results of such an analysis of a sample from the Cedar Lake marl beds in Montcalm county, Mich., gave the following results. The sample used was collected from a hole made with a spade by cutting away the turf over the marl, then taking out sufficient marl to be sure that there was no peat or other surface matter present and the material used taken from a spadeful thrown out from two or three feet below this level. From this sample about thirty grams were taken and treated as described above, and after the finer material had been separated from the coarser by washing and drying, the latter was passed through a set of standard gauge sieves, twenty, forty, sixty, eighty, and one hundred meshes to the linear inch, after which all shells and recognizable shell fragments, sand grains and vegetable débris, up to the sixty-mesh siftings, were removed and weighed separately. This gave the following grades: (1) Material too coarse to pass through the twenty-mesh sieve, (2) that held by the forty-mesh, (3) that held by the sixty-mesh, (4) that held by the eighty-mesh, (5) that held by the hundred-mesh, (6) that which passed through the hundred-mesh, (7) that which was filtered out, (8) water soluble salts, (9) shells, shell fragments, and miscellaneous matter.

The following is the result of the analysis of Cedar Lake marl made and graded as described:

Grade (1)	-	-	-	-	-	-	32.25 %
(2)	-	-	-	-	-	-	6.06
(3)	-	-	-	-	-	-	7.58
(4)	-	-	-	-	-	-	2.90
(5)	-	-	-	-	-	-	4.81
(6)	-	-	-	-	-	-	15.64
(7) }	-	-	-	-	-	-	30.52 <sup>1</sup>
(8) }	-	-	-	-	-	-	0.28
(9)	-	-	-	-	-	-	
							100.04

A second analysis was made from a specimen made up of twenty samples taken by boring with an auger over about one-half of the deposit at Littlefield Lake, Isabella county, most of the samples coming from a depth of at least twenty feet, six to eight meters below the surface of the deposit. This analysis gave the following results:

Grade (1)	-	-	-	-	-	-	31.52 %
(2)	-	-	-	-	-	-	14.48
(3)	-	-	-	-	-	-	12.76
(4)	-	-	-	-	-	-	2.56
(5)	-	-	-	-	-	-	6.74
(6) }	-	-	-	-	-	-	30.42
(7) }	-	-	-	-	-	-	0.27 <sup>2</sup>
(8)	-	-	-	-	-	-	1.04
(9)	-	-	-	-	-	-	
							99.79

A third sample, from the holdings of the Michigan Portland Cement Company at Coldwater, Mich., a fine high grade white marl, very powdery, gave the following: Weight of sample, 20.— grams.

Grade (1)	-	-	-	-	-	-	0.36 %
(2)	-	-	-	-	-	-	3.53
(3)	-	-	-	-	-	-	6.51
(4)	-	-	-	-	-	-	3.34
(5)	-	-	-	-	-	-	6.44
(6)	-	-	-	-	-	-	28.99
(7)	-	-	-	-	-	-	49.12
(8)	-	-	-	-	-	-	Not determined.
(9)	-	-	-	-	-	-	0.69
Loss and soluble matter (by difference)							1.02
							100.00

<sup>1</sup> In this case determined by drying down the residue and weighing.

<sup>2</sup> The soluble matter contains a certain undetermined amount of alkaline chlorides as well as a soluble calcium salt.

These samples represent (1) central, (2) north central, and (3) southern parts of the lower peninsula respectively, and may be taken as typical of the marl deposits of Michigan. When it is stated that, in general, it is easily possible to recognize with a simple microscope the particles which are held by the one hundred-mesh sieve, or even those which pass through it, if the finer matter has been carefully separated by washing, as characteristic *Chara* incrustation or *Schizothrix* concretions, it will be seen that these results show conclusively that a large part of the marl from these three samples is identifiable as of algal origin, and studies of the marls from other localities give similar results.

The Coldwater sample (3) was exceedingly fine in texture, and it was difficult to avoid loss in sorting and weighing, as every current of air carried away some of the particles, and some also adhered to sieves and weighing dishes in spite of all precautions. Even this sample shows nearly 50 per cent. of easily identified *Chara* incrustation. The fineness of the particles in a given marl bed varies much in different parts of the bed, and the degree of fineness is probably chiefly dependent upon the conditions of current and wave action under which the bed was formed, that which was deposited where the wave or current action was strong being coarser than that in stiller water or that on the lee side of exposed banks. This fact was noted at Littlefield Lake when samples of marl were collected along exposed shores above the wave line, which were 95 per cent. coarse fragments of *Chara* incrustation and *Schizothrix* nodules, while in other parts of the shore line the marl was of such fineness that it was like fine, white clay. The fragments of the *Chara* incrustation are generally easily recognized even when of minute size, because they preserve, usually very perfectly, the peculiar form of the stem and branches of the plant. This structure of the stem and branches is, in brief, a series of small tubes, grouped about a larger central one, and is easily seen with the unaided eye in larger fragments. Even when the tubes have been crushed, as is the case with many of the thinner ones,

it is frequently possible to recognize fragments of them with the compound microscope. Finally the incrustation is distinctly crystalline in ultimate form of the constituent particles, and when it has disintegrated the crystals and their fragments are found to constitute a large per cent. of the finer particles of the resulting marl. On the growing tips of the younger branches and the leaves of *Chara*, numbers of isolated crystals of calcium carbonate may be seen. Farther back on stems and branches the crystals become more numerous, then coalesce into a thin, fragile covering, and finally on the lower part of the plant the covering becomes dense and thick. It is evident therefore that the decay of the younger parts of the plants would furnish a mass of more or less free or loosely aggregated crystals of microscopic size, which would retain their crystalline form, in some degree at least, for an indefinite time and be recognizable, hence the presence of microcrystals in marl may furnish additional evidence as to the origin of the deposits.

The larger fragments of *Chara* incrustation as found in marl are frequently much thicker and heavier than any which occur among fragments of recent origin, *i. e.*, those obtained from any part of living, vigorously growing *Chara* from the beds of the plant existing in ponds from which the marl may have been obtained. While this subject needs further investigation, it is probable that such thickened incrustations have originated in several ways, the principal ones being, if the writer's notes have any bearing on the subject, as follows:

1. On short, stunted plants that grow for a long time on unfavorable soil, such as sand or pure marl. Such plants have relatively very short internodes and generally thick incrustations, much thicker than those on plants growing normally.
2. From the growth of the lime-secreting, blue-green algae, such as *Schizothrix*, *Rivularia*, etc., either upon living *chara* or upon the fragments of broken incrustation, as a nucleus. Such a growth might produce considerable thickening of the *Chara* incrustation.
3. From the inclusion of the fragments within the nodules

formed by the growth of the incrusting blue-green algae, in shallow water, and the subsequent destruction of the nodules by wave or other disintegrating action. In this case a thickened fragment may be left either free or attached to other material. Several fragments may be cemented together, and such aggregations have been observed.

4. By the deposition of calcium carbonate on fragments of incrustation, the source of the salt deposited being soluble calcium-organic compounds left free in the water by the decay of dead *Chara*, the precipitation being caused by the reducing action of chemical compounds derived from the decay of organic matter or the growth of bacteria. It may be conceived also that the calcium carbonate thus deposited might also act as a cementing material to fasten the finer particles of marl to the incrustation as a nucleus.

5. By the deposition in more or less coarsely crystalline form of calcium carbonate which is dissolved by water percolating through the marl. This is probably considerable in amount and takes place in a manner analogous to, if not identical with, the formation of concretions in clays and shales. It is probable that in this way the crystals may be formed, which rather rarely are found filling the cavities in the *Chara* incrustations, left by the large axial cells of the plant. The fact that in the great majority of cases these cell cavities are entirely empty or are simply mechanically filled with fine particles of marl, is a most serious objection to considering that this form of chemical precipitation is an important one in the history of marl, but that it is occasionally operative is extremely probable.

6. It is possible that the thick incrustations may have been formed at some earlier period in the history of the lakes when conditions for the development of the plant forms and their activities were greater. This is not probable however, for the thick incrustations are often found from the surface of the marl beds throughout the entire deposits.

In addition to the marl analyses given above a check analysis was made of a specimen of material made up from the washings

and fragments of a mass of Chara plants collected from Cedar Lake, and allowed to die slowly and to break up in water kept cold and fresh by conducting a small stream from the hydrant through it. The plants gradually died, broke up, and settled to the bottom of the containing vessel and seemed to undergo farther disintegration there from the growth of fungi, eventually forming a relatively finely divided deposit which was of rather dark color, when wet. A quantity of this was dried at 100°C., some of the longer and larger fragments of stems were removed, and the residue was weighed and subjected to the same treatment as the marl samples. The analysis gave the following:

Grade (1)	-	-	-	-	-	-	1.12%
(2)	-	-	-	-	-	-	24.43
(3)	-	-	-	-	-	-	14.63
(4)	-	-	-	-	-	-	8.26
(5)	-	-	-	-	-	-	7.81
(6) {	-	-	-	-	-	-	33.83
(7) }	-	-	-	-	-	-	
(8)	-	-	-	-	-	-	0.39
(9)	-	-	-	-	-	-	0.12
Soluble organic matter and loss	-	-	-	-	-	-	9.41
							100.00

It will be seen that nearly as much fine matter was present in this material as in the finest of the marls analyzed, and that the finer grades of sifted material are quite as well represented as in the finer marl. The material is somewhat more bulky for a given weight and is perhaps slightly darker in color, but not much more so than many samples of marl.

Grade for grade it is identical in appearance and structure to the marl samples, and the only possible difference that can be detected is the slightly green tint and the organic matter present in the plant residue. It is also noticeable that the larger pieces do not show as thick an incrustation as do the larger pieces from the marl samples and, of course, Schizothrix and other coarse matter is not present.

It will be seen by inspecting the analyses, that shells and recognizable shell fragments are but a very insignificant part of



the total quantity of the marl. It is surprisingly small when all things are taken into account. While it is probably true that not all the minute shell fragments have been separated in any of these analyses, it is also true that the weight of such overlooked particles is more than counterbalanced by marl fragments which are included within the cavities of the whole shells, and adhere to both broken and whole shells in crevices and sculpturings in such a way as to refuse to become separated in the processes of washing out the marl. The whole shells are mainly small, fragile forms, many of them immature, and it is evident that they would be broken by any action that would crush the *Chara* incrustation.

A second line of investigation took into consideration the milky appearance of the waters of some marl lakes. This has been considered by some investigators as possibly due to the presence of calcium carbonate precipitated from the water either by the liberation of dissolved carbon dioxide from the water and hence from the calcium bicarbonate or by change of temperature of the water after it has reached the lakes.

The writer has not found among the marl lakes of the southern peninsula of Michigan that those with turbid water were common, even where marl banks were apparently forming with considerable rapidity.

"Merl" or Marl Lake in Montcalm county, situated on the same stream as Cedar Lake and a mile or more below it, is, however, one of the lakes in which the water is usually of almost milky whiteness, and has sufficient suspended matter in it to render it nearly opaque for depths of a meter or a little more. The conditions in this lake are widely different from those at Cedar Lake and other marl lakes in the vicinity and are suggestive of the cause of the turbidity. At Cedar Lake there is a border of grassy or sedgy marsh extending around the lake on three sides and generally underlaid by marl, and the lake bottom slopes sharply and abruptly from the edge of the marsh to a depth of at least ten meters. In other words the lake is simply a deep hole, with steep sides, and perhaps represents the

deepest part of the more extensive lake which formerly occupied the area included by the marsh and marl beds. This marsh covering is general on the marl beds of the region and the lake may be said to be a typical marl lake for the locality in which it lies, for there are several others near by which are practically identical in essential points of structure.

At Marl Lake, however, the filling of the lake has not reached the same stage. There is practically no open marsh, but the lake is shallow for seventy-five or a hundred meters from the shore, then abruptly deepens to an undetermined depth over a relatively small area. The bottom over the shallow area is of pure white marl, and the water is apparently not more than sixty or seventy centimeters deep at the margin of the central hole, while near the shore it is scarcely one-third as deep. In brief, here is a lake in which there is a broad platform of marl surrounding a deep hole, which again is all that remains of the deep water of a lake which is filling with marl. Boring shows that the bed of the lake is nearly as far below the surface under the marl platform, as where the marl has not yet been deposited.

Upon the shoreward edges of the platform and in small areas farther out upon it, the turf-forming plants are beginning to establish themselves, but as yet they have not made any marked impression, seeming to have a hard struggle to get a foothold. The conditions are then a broad area of shallow water overlying a wide platform of marl, which, if a strong wind should reach it, would be stirred to its depths, and with it the lighter parts of the marl upon which it rests. The marl thus stirred up, in turn, is carried to all parts of the lake by surface and other currents and makes the water turbid. These facts led to an investigation as to the rapidity with which marl, once stirred up, would settle out of perfectly still water, and some interesting results were obtained. The experiments were made as follows: (1) A glass tube 1.58 meters long and 2.5 centimeters wide was filled with distilled water, into which a quantity of finely divided marl was turned and the tube was shaken to insure a thorough mixing of water and marl. The tube was then

clamped into a vertical position and left perfectly still until the marl had settled out, notes being made, daily at first, of the rate of settling. In the beginning, the heavier particles settled rapidly, forming, as does clay in settling from water with which it is mixed, stratification planes, which, however, after a few days disappeared, and only the lighter parts of the marl remained in suspension. These were distinctly visible for five weeks, on looking through the tube towards a window, and at the end of six weeks, a black object lowered into the tube in a well-lighted room, was not visible beyond ninety centimeters from the surface of the water. (2) A glass cylinder with a foot, 38<sup>cm</sup> high and 7<sup>cm</sup> wide, having a capacity of a little more than a liter was nearly filled with distilled water and the residue from the washings of a sample used in analysis was thoroughly mixed with it, and set aside, notes being made as before. This material subsided rather more slowly than the other, and at the end of ten weeks, under daylight illumination, the bottom of the vessel was barely visible when one looked down through the water from above.

The results obtained by Barus<sup>1</sup> in his work on the subsidence of solid matter into suspension, in liquids, show that settling is much more rapid in water containing dissolved salts, even small proportion, than in distilled water, and the foregoing experiments were checked as follows: (1) A cylinder about the size of the one used in the second experiment was filled with water in which a small amount of calcium chlorid had been dissolved, and ammonium carbonate was added until a precipitate was formed. This was stirred thoroughly and left to settle. In three days the precipitate had fully subsided and the liquid was clear. (2) Two cylinders of equal size were filled, one with distilled water, the other with water from a river fed, in part, by marl lakes. Equal quantities of fine marl were shaken up with the water and the rate of settling was compared. The marl was not as fine as that used in the other studies and settled more rapidly. The river water was clear in fifteen days, while the

<sup>1</sup>CARL BARUS: "Subsidence of Fine Solid Particles in Liquids." Bull. of the U. S. Geol. Surv., No. 36.

distilled water was not clear when the experiment terminated, but was nearly so, showing that the subsidence was not quite so rapid in distilled water as in natural lake or river water.

These results indicate that, if for any cause the marl in a marl lake is stirred up effectually, as it may be in those where the beds are exposed to wave action, the water will remain turbid for some time; even in summer time the chances are that there will be sufficiently frequent high winds to keep the water always turbid. It may be stated that in some of the lakes which have been studied by the writer, the marl beds have filled the entire lake to within a fraction of a meter of the surface of the water, with some parts only a few centimeters deep. Until such shallows are occupied by vegetation the water is likely to be turbid from the mechanical action of waves upon the deposits. At Littlefield Lake, described elsewhere,<sup>1</sup> the water is only slightly turbid, although there are extensive shallows and exposed banks, but there the body of water is extensive and of considerable depth, while the greater part of the exposed marl is granular and the particles too coarse to be held long in suspension, and the finer deposits too small and too well protected to be reached by effective waves, so that the amount of suspended marl is not great enough to produce marked turbidity in the entire body of water.

It may be worthy of note that the residue of suspended matter, filtered out from the sample of *Chara* fragments (analysis (4) above) was sufficiently fine to give a marked turbidity to distilled water for several days, and at the time of filtering had not subsided, demonstrating the fact that very finely divided particles may originate from the simple breaking up of the *Chara* plants by ordinary decomposition of the vegetable matter.

It is difficult to account for the fact that the deeper parts of marl lakes are generally free from any thick deposits of a calcareous nature. Lack of records of sufficient exploration makes any statement purely tentative, but about seven to nine meters<sup>2</sup>

<sup>1</sup> C. A. DAVIS: "A Remarkable Marl Lake," *JOUR. GEOL.*, Vol. VIII, No. 6.

<sup>2</sup> WESENBERG-LUND: Lake-Lime, Pea Ore, Lake Gytje. *Særtryk af Meddelelser fra Dansk Geologisk Forening*, No. 7, p. 156.

seems to be the limit of depth of recorded occurrence of *Chara* plants. The remains of the plants, then, would only accumulate, in place, above that depth, and the material reaching greater depths would be that held in suspension in the water, and hence be relatively very small in quantity and accumulate slowly. A possible additional cause of slow accumulation is that in the greater depths, *i. e.*, over ten meters, the greater abundance of dissolved carbon dioxide held in solution by pressure dissolves the finer particles of marl which reach these depths.

From these investigations it seems (1) that marl, even of the very white pulverulent type, is really made up of a mixture of coarser and finer matter covered up and concealed by the finer particles, which act as the binding material. (2) That the coarser material is present in the proportion of from 50 to 95 per cent. (3) That this coarser material is easily recognizable with the unaided eye and hand lens, as the incrustation produced on the algae, *Schizothrix* and *Chara*, principally the latter, to particles less than one one-hundredth of an inch in diameter. (4) That the finer matter is largely recognizable under the compound microscope as crystalline in structure, and is derived from the algal incrustation by the breaking up, through decay of the plants, of the thinner and more fragile parts, or by disintegration of the younger parts not fully covered. (5) That some of this finer matter is capable of remaining suspended in water a sufficiently long time, after being shaken up with it, to make it unnecessary to advance any other hypothesis to explain the turbidity of the waters of some marl lakes, than that it is caused by mechanical stirring up the marl by wave or other agency. (6) That shells and shell remains are not important factors in the production of the marl beds which are of largest extent. (7) That there is in marl a small amount of a water soluble calcium salt, readily soluble in distilled water, after complete evaporation.

<sup>2</sup>A. J. PIETERS: Plants of Lake St. Clair, Bull. Mich. Fish Commission, No. 2, p. 6.

Studies were undertaken to determine the method of concentration and precipitation of the calcium carbonate by *Chara*.

As has already been indicated elsewhere, the calcium carbonate is present on the outside of the plant as an incrustation, and this is made up of crystals, which are rather remote and scattered on the growing parts of the plants, and form a complete covering on the older parts, which is uniformly thicker on the basal joints of the stems than it is on the upper ones. Considering the hypothesis that the deposition of the salt was the result of purely external chemical action as not fully capable of satisfying all the existing conditions, the formation of the incrustation was taken up as a biological problem, and an investigation was made upon the cell contents of *Chara*, first, microscopically by the study of thin sections. Various parts of the plant were sectioned while still living, and the attempt was made to find out if the calcium carbonate was present as a part of the cell contents in recognizable crystalline form. Various parts of the plant were examined, but no crystals undoubtedly in place among the contents of the cells were observed, although numbers were to be seen on outside walls of all cells.

Next an attempt was made to determine the presence of the calcium in soluble form in the cell contents, by the use of dilute neutral solution of ammonium oxalate. An immediate response to the test was received by the formation of large numbers of minute, characteristic, octahedral crystals of calcium oxalate on the surface and imbedded in the contracted protoplasmic contents of the cell. The number of these crystals was so large, and they were so evenly distributed through the cell contents, that it was evident that a large amount of some soluble calcium salt was diffused through the cell sap of the plant. The next step was to isolate this compound and to determine its composition. A considerable quantity of the growing tips of *Chara* were rubbed up in a mortar and the pulp was thoroughly extracted with distilled water. This water extract was filtered and tested to determine the presence of calcium and an abundant precipitate obtained by using ammonium oxalate,

which, on being separated and tested, proved to be calcium oxalate. It was evident that the calcium salt in the plant was stable and readily soluble in water. This latter fact was farther demonstrated by evaporating some of the extract to dryness and again taking it up with water. Almost the entire amount of the calcium salt was redissolved, only a small portion of it becoming insoluble and precipitating as the carbonate. This ready solubility demonstrated the fact that the salt was not derived from the incrustation on portions of the plant used, and the same fact excluded from the list of possible compounds, salts of some of the mere common organic acids found in plant juices, which are insoluble.

Qualitative chemical tests were, however, made to determine, if possible, whether any of these acids were present with negative results, and it was demonstrated by this means that there was but a single salt present and not a mixture. Search was then made to determine the acid present, and a result obtained which was so unexpected that it was seriously questioned and the work was gone over again. The second result confirmed the first and the work of ascertaining the correctness of these two results was turned over to Mr. F. E. West, Instructor in Chemistry in Alma College, who had had special training and much practice in organic analysis. His work was done entirely independently, with material gathered at a different season, and by another method of analysis, but his results were identical with my own, and show that calcium exists in the water extract of *Chara* as calcium succinate. The fact that the succinate is one of the few water soluble calcium salts and that there is a soluble salt of the metal in the cell sap of the plant makes it probable that this is the compound of the metal which the plant accumulates in its cells.

It is not possible from actual investigation to explain the method by which the calcium salt is abstracted from the water, where it exists as the acid- or bi-carbonate or the sulphate<sup>1</sup> in

<sup>1</sup> It has been shown that *Chara* decomposes several calcium salts, the sulphate among others.

small per cent., and is concentrated in the cells of the plant as calcium succinate and later deposited upon the outside of the same cells as the normal or monocarbonate in crystalline form in considerable quantities.

Some culture experiments which were undertaken by the writer to determine under what conditions of soil, light, and temperature *Chara* thrives best, incidentally demonstrated that the plant actually gets its lime from the water and not from the soil. One of the soils which was used as a substratum in which to grow plants was pure quartz sea-sand which had been washed with acid to remove any traces of calcium salt which might be present. The plants grew in this medium readily, and on the newer parts developed nearly, if not quite, as many calcium carbonate crystals as plants growing in pure marl. It should be apparent, however, to even the casual observer that the plants cannot take all the lime they precipitate from the soil, or even a considerable part of it, for if they did the marl beds, being made up principally of *Chara* remains, would never have accumulated, for the material would have been used over and over again and could not increase much in amount, if it increased at all. In the present state of our knowledge of the life processes of aquatic plants, it seems hardly possible to state the probable method of the formation of the calcium succinate, or even the probable use of it to the plant, and no attempt will be made by the writer in the present paper to do so. It does seem probable, however, that this compound accumulates in the cells, until it reaches sufficient density to begin to diffuse through the cell walls by osmosis. Outside the cells, or in its passage through the walls, it is decomposed directly into the carbonate, possibly by oxidation of the succinic acid by free oxygen given off by the plants, possibly by some substance in the cell walls, or, more probably, by the decomposition of the acid by some of the organic compounds in the water, such as the organic ferments, due to bacterial growth in the organic debris at the bottom of the mass of growing *Chara*. The water extract of *Chara* rapidly changes on standing, undergoing putrefactive



decomposition, becomes exceedingly offensive in odors developed, and calcium carbonate crystallizes out on the bottom and sides of the containing vessel, while the succinic acid disappears, gas, possibly carbon dioxide, being given off more or less abundantly. Whether these changes takes place on the outside of the living plants, in the cell walls, or in the water surrounding the plants has not yet been determined.

Sufficient evidence is here presented, however, if the writer's conclusions are correct, to show that the plants under discussion are active agents in the concentration of calcium salts in the fresh water lakes of Michigan, and that they alone have produced a very large part of the marl which has accumulated in these lakes. It seems probable also that the principles developed by these studies are of very wide application in working out problems presented by formations developed under similar conditions elsewhere.

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July 1, 1901.